

Description

BICYCLE CRANK ASSEMBLY

Background of the Invention

- [1] The present invention relates to bicycle crank assemblies and more particularly to a bicycle crank assembly that minimizes interfaces or joints between assembly parts.
- [2] A typical bicycle includes a crank assembly for transferring pedal force of the rider to a drive chain of the bicycle. The crank assembly includes crank arms that are attached to a bearing assembly, commonly called a bottom bracket, rotatably mounted inside the bicycle frame. The bottom bracket includes a spindle that is attached to the crank arms. Since the bearings are located inside of the bicycle frame, their sizes are determined by the size of the frame. The size of the frame also governs a diameter of the bottom bracket spindle.
- [3] One drawback of a typical crank assembly is that each crank arm must be assembled onto each spindle end after the bearings are mounted in the bicycle frame. This configuration complicates the assembly process, resulting in numerous joints and parts. Another drawback is variances in frame tolerances and assembly procedures that can cause problems with typical crank assemblies that are not designed to accommodate these variances in tolerances.
- [4] Another drawback of a typical crank assembly is the alignment of bearing races. To maximize bearing life of the bottom bracket it is critical that the bearing races be correctly aligned such that the bearings are not subjected to additional axial loading due to part tolerances or assembly procedures. Bearings that are over-loaded quickly fail. Most current bearing assemblies require tight tolerances or strict assembly procedures to prevent bearings from becoming axially over-loaded.
- [5] Further, typical bottom bracket systems use the same size and method of loading for each bearing unit used in bottom bracket. However, this makes it impossible to balance the loads placed upon the bearings so that bearing life is maximized. Also, most spindles are integrated within the bearing units themselves such that when the bearings wear out the entire unit must be replaced.

Summary of the Invention

- [6] One object of the present invention is to provide a bicycle crank assembly with fewer parts and interfaces between pieces, minimizing manufacturing cost.
- [7] Another object of the present invention is to provide a bicycle crank assembly having bearing assemblies disposed outboard from the bicycle frame, resulting in the size of the bearings and the bottom bracket not being constrained by the size of the bicycle frame.
- [8] Another object of the present invention is to provide a bicycle crank assembly that is easy to install and robust with respect to installation procedure variations.
- [9] Another object of the present invention is to provide a bicycle crank assembly that

is easy to disassemble for routine maintenance.

[10] Another object of the present invention is to provide a bicycle crank assembly that does not rely on assembly tolerances or procedures to adjust the axial bearing loads and can accommodate large tolerance deviations of the frame.

[11] Another object of the present invention is to provide a bicycle crank assembly that balances the loading of the bearings such that bearing life of the system is maximized.

[12] Another object of the present invention is to provide a bicycle crank assembly that is well sealed to protect the bearings from contamination yet still allow an escape path for contaminants that may get through the seal system such that the potential for bearing damage is minimized.

[13] The present invention provides a bicycle crank assembly mountable to a bicycle frame. The crank assembly generally includes a spindle, a drive crank arm, a non-drive crank arm, first and second bearing assemblies for rotatably supporting the spindle. In one embodiment of the present invention, the drive crank arm is formed monolithically as one-piece with a first end of the spindle and the non-drive crank arm is operatively connected to a second end of the spindle. In another embodiment of the present invention, the drive crank arm is made from fiber-resin composite material and is bonded to the first end of the spindle. These two embodiments of the drive crank arm/spindle reduce the number of parts and are not affected by variations in the width of the frame. The first bearing assembly is arranged between the first end of the spindle and the bicycle frame and includes a bearing located outboard of the bicycle frame. The second bearing assembly is arranged between the second end of the spindle and the bicycle frame and includes a bearing located outboard of the bicycle frame.

[14] In another embodiment of the present invention, the first and second bearing assemblies further include a bearing adapter and an external seal. The bearing adapter includes a flange portion and a threaded portion. The threaded portion is matingly engageable with corresponding threads on the bicycle frame. The bearing is disposed in the flange portion that is located outboard of the bicycle frame. The external seal includes a metal portion and a rubber portion having an inner rubbing element and an outer rubbing element. The outer rubbing element of the external seal is received in a groove of the flange portion of the bearing adapter. The inner rubbing element seals with the spindle. The groove, inner and outer rubbing elements and the spindle are configured such that the friction between the inner rubbing element and the spindle is greater than the friction between the outer rubbing element and the groove of the flange portion of the bearing adapter. The bearing is a ball bearing having inner and outer races, a plurality rolling elements and a seal. The seal rotates with the outer race and rubs against the inner race. In contrast to the seal of the bearing, the external seal rotates with the inner race and rubs on its outer diameter against the bearing adapter. The bearing assembly is protected by two seals, the external seal and the seal of the bearing. The two seals act together to minimize the potential for contamination of the

bearings while allowing any water that might enter the external seal to be easily expelled.

- [15] In another embodiment of the present invention, a fastener secures the non-drive crank arm to the spindle. The fastener generally includes a bolt, a washer and a cup. The bolt has a flange portion, a threaded portion, a bore and a tool-engaging portion formed on an inner surface of the bore. The flange portion has an inner side surface and an outer side surface. The inner side surface is perpendicular to an axis of the bolt and the outer side surface is at angle between 40 and 70 degrees relative to the bolt axis. The threaded portion of the bolt matingly engages corresponding threads on an inner surface of the spindle. The cup includes a threaded portion and a flange portion. The threaded portion matingly engageable with corresponding threads on the non-drive crank arm located exterior to the bolt, resulting in the bolt disposed between the flange portion of the cup and the non-drive crank arm. The flange portion of the cup has an inner side surface and a tool-engaging portion. The inner side surface is configured to be at an angle corresponding to the outer side surface of the bolt such that the inner side surface of the cup abuts against the outer side surface of the bolt. With this configuration, the cup acts as an axial stop whereby when the bolt is unscrewed, the non-drive crank arm is extracted from the spindle. Accordingly, the crank assembly of the present invention is easy to disassembly. Further, the bolt may not be lost because it is always contained in the non-drive crank arm and the height of the bolt and the cup system is minimized, thereby increasing the ankle clearance for the rider.

- [16] These and other features and advantages of the present invention will be more fully understood from the following description of certain embodiments of the invention, taken together with the accompanying drawings.

Brief Description of the Drawings

- [17] In the drawings:
- [18] FIG. 1 is a side view of a bicycle that includes a crank assembly in accordance with one embodiment of the present invention;
- [19] FIG. 2 is a cross-sectional view of the crank assembly of FIG. 1;
- [20] FIG. 3 is an isometric partial cross-sectional view of a spindle and a drive crank arm of FIG. 2;
- [21] FIG. 4 is an isometric partial cross-sectional view of a non-drive crank arm of FIG. 2;
- [22] FIG. 5 is an isometric partial cross-sectional view of a first bearing assembly of the crank assembly in accordance with one embodiment of the present invention;
- [23] FIG. 6 is an isometric partial cross-sectional view of a second bearing assembly of the cranks assembly in accordance with on embodiment of the present invention;
- [24] FIG. 7 is a cross-sectional view of a seal of FIG. 5;
- [25] FIG. 8 is a cross-sectional view of a seal of FIG. 6;
- [26] FIG. 9 is an isometric partial cross-sectional view of a washer of FIG. 2;

- [27] FIG. 10 is an isometric partial cross-sectional view of a bolt of FIG. 2;
[28] FIG. 11 is an isometric partial cross-sectional view of a cup of FIG. 2;
[29] FIG. 12 is an isometric partial cross-sectional view of a spindle and a drive crank arm for the crank assembly in accordance with another embodiment of the present invention; and
[30] FIG. 13 is an isometric partial cross-sectional view of a spindle and a drive crank arm for the crank assembly in accordance with another embodiment of the present invention.

Detailed Description

- [31] FIGS. 1-11 illustrate a crank assembly 10 for a bicycle 12 in accordance with one embodiment of the present invention. Looking to FIG. 1, the bicycle 12 may be any type of bicycle, and in this embodiment the bicycle 12 includes a frame 14 having a top tube 16, a head tube 18, a down tube 20 extending downwardly from the head tube 18, a seat tube 22 supporting a seat 24 and extending downwardly from the top tube 16, a bottom bracket 26 (FIG. 2) disposed at the junction of the down tube 20 and the seat tube 22, a pair of seatstays 28 extending rearwardly and downwardly from the top tube 16, and a pair of chainstays 30 extending rearwardly from the bottom bracket 26 or frame shell. The crank assembly 10 is rotatably mounted to the frame shell 26. A rear wheel 32 is rotatably supported at the junction of the seatstays 28 and the chainstays 30. A front wheel 34 is supported by a fork 36 that is supported by the head tube 18. A chain 38 extends between and engages at least one chainring 40 mounted to the crank assembly 10 and at least one sprocket 42 mounted to the rear wheel 32. The crank assembly 10 is rotated to generate forces propagating through the chainring 40, chain 38, sprocket 42 and rear wheel 32 that propel the bicycle 12 forward.
- [32] Looking to FIG. 2, the crank assembly 10 is rotatably mounted to the frame shell 26. The crank assembly 10 generally includes a spindle 44, first and second bearing assemblies 46, 48, a drive crank arm 50 and a non-drive crank arm 52. The spindle 44 extends through a spacer tube 53 that is disposed in the frame shell 26. The spindle 44 includes a first end 54 and a second end 56. The drive crank arm 50 is connected to the first end 54 of the spindle 44 and a fastener 55 secures the non-drive crank arm 52 to the second end 56 or free end of the spindle 44. The first bearing assembly 46 is arranged between the first end 54 of the spindle 44 and the frame shell 26 and the second bearing assembly 48 is arranged between the second end 56 of the spindle 44 and the frame shell 26, each bearing assembly 46, 48 rotatably supporting the spindle 44.
- [33] Looking to FIG. 3, the spindle 44 includes a flange portion 58, a drive adapting portion 60, bearing race portions 62, 64, a shoulder portion 66, a non-drive adapting portion 68 and a threaded portion 70. In this embodiment, the drive adapting portion 60 includes a plurality of splines (not shown) for mating with a plurality of splines (not shown) on the drive crank arm 50. Similarly, the non-drive adapting portion 68

includes a plurality of splines 72 for mating with a plurality of splines 74 (FIG. 4) on the non-drive crank arm 52. An outer diameter of the non-drive adapting portion 68 of the spindle 44 is smaller than an outer diameter of the drive adapting portion 60 of the spindle 44. Further, the bearing race portion 64 is smaller than the bearing race portion 62 with the shoulder portion 66 arranged therebetween.

[34] The drive crank arm 50 includes a pedal adapting portion 76 for receiving a pedal (not shown), a crank arm portion 78, a spindle adapting portion 80 and support projections 82 for receiving at least one chainwheel 40. The spindle adapting portion 80 of the drive crank arm 50 includes a cylindrical bore 84 and the plurality of splines (not shown) on an inner surface of the bore 84 for mating with the splines (not shown) of the spindle 44. The flange 58 of the spindle 44 abuts against an outer side surface 86 of the cylindrical bore 84. In this embodiment, the spindle 44 is press-fitted into the cylindrical bore 84 of the drive crank arm 50. Alternatively, the crank arm may be heat-shrunk onto the spindle. With both of these configurations, the spindle 44 is integrated with the drive crank arm 50 in a non-rotatable manner.

[35] Looking to FIG. 4, the non-drive crank arm 52 includes a pedal adapting portion 88 for receiving a pedal (not shown), a crank arm portion 90, and spindle adapting portion 92. The spindle adapting portion 92 includes a cylindrical bore 94, an inner side surface 96 and the plurality of splines 74 on a portion of an inner surface 97 of the cylindrical bore 94 for mating with the splines 72 on the non-drive adapting portion 68 of the spindle 44. The splines 74 on the cylindrical bore 94 and the corresponding splines 72 on the spindle 44 are tapered in an axial direction such that as the non-drive arm 52 is installed onto the second end 56 or free end of the spindle 44, the fit between the mating splines 72, 74 tightens. This ensures that the non-drive crank arm 52 is tightly engaged with the spindle 44 to prevent relative movement between them. Threads 98 are formed on a portion of the inner surface 97 of the cylindrical bore 94. The portion of the cylindrical bore 94 having the threads 98 has a larger diameter than the portion of the cylindrical bore 94 having the splines 74. The two diameters meet at a surface 100 in the cylindrical bore 94. The surface 100 is perpendicular to the axis of the cylindrical bore 94.

[36] Looking to FIG. 5, the first bearing assembly 46 includes a bearing 102, a bearing adapter 104 and an external seal 106. The bearing adapter 104 includes a flange portion 108 and a threaded portion 110. The threaded portion 110 mates with corresponding threads 112 on an inner surface 114 of the frame shell 26 and is tightened until flange portion 108 contacts an outer side surface 116 of the frame shell 26. The bearing 102 is press-fitted into the flange portion 108 of the bearing adapter 104 such that the bearing 102 is located distally outboard from the outer side surface 116 of the frame shell 26. The bearing 102, in this embodiment, is a roller bearing that includes an inner race 118, an outer race 120, seals 122 and a plurality of rolling elements 124. The seals 122 are rotatably fixed to the outer race 120 such that inner diameters of the

seals 122 rub against the inner race 118.

[37] Looking to FIG. 6, the second bearing assembly 48 includes a bearing 126, a bearing adapter 128, an external seal 130 and a bearing reducer 132. Similar to the first bearing adapter 104, the second bearing adapter 128 includes a flange portion 134 and a threaded portion 136 that mates with corresponding threads 138 on an inner surface 114 of the frame shell 26. The bearing 126 is press-fitted into the flange portion 134 of the bearing adapter 128 such that the bearing 126 is located distally outboard from the outer side surface 140 of frame shell 26. The bearing 126, similar to the first bearing 102, includes inner and outer races 142, 144, seals 146 and a plurality of rolling elements 148. As stated above, the outer diameter of the non-drive adapting portion 68 of the spindle 44 is smaller than the outer diameter of the drive adapting portion 60 of the spindle 44 and thus the bearing reducer 132 is used to make the inner diameter of the bearing 126 smaller to fit on the smaller outer diameter of the non-drive adapting portion 68 of the spindle 44. The bearing reducer 132 includes a flange portion 150 and a cylindrical portion 152. The cylindrical portion 152 of the bearing reducer 132 is press-fitted into the bearing 126 from the inside out until the flange portion 150 of the reducer contacts the inner race 142 of the bearing 126. The bearing reducer 132 allows the same size bearing 102, 126 to be used for both bearing assemblies 46, 48. Alternatively, the second bearing 126 may be a different size than the first bearing 102, resulting in the bearing reducer 132 not being needed. With different sized bearings, the diameter of the inner race of the second bearing would be smaller than the diameter of the inner race of the first bearing.

[38] Since the chainring 40 is closer to the first bearing assembly 46 than the second bearing assembly 48, the first bearing assembly 46 has greater radial force applied to it than the second bearing assembly 48 due to pedaling forces applied to the crank arms and chain forces generated through the chainring 40. Since the life of the bearing increases if the loading on the bearing is minimized, it is desirable to balance the forces applied to the first and second bearing assemblies 46, 48 so that the forces applied to each bearing are minimized. One way to achieve this is for the second bearing assembly 48 to carry both axial and radial forces, while the first bearing assembly 46 carries only radial forces, resulting in the life of the bearings being maximized.

[39] Looking to FIG. 7, the external seal 106 of the first bearing assembly 46 includes a rubber portion 154 and a metal portion 156. The rubber portion 154 includes an outer rubbing element 158 and an inner rubbing element 160. The outer rubbing element 158 is received in a groove 162 (FIG. 5) in the flange portion 108 of the bearing adapter 104. The groove 162 is configured such that the rubber portion 154 of the seal 106 must be slightly deformed to be installed into the groove 162. Once installed the rubber portion 154 of the seal 106 returns to its original shape, thus be retained inside the groove 162. The diameter of the inner rubbing element 154 is smaller than the

diameter of the spindle 44 at the axial location of the spindle 44 where the inner rubbing element 160 contacts the spindle 44 when the crank assembly 10 is completely installed. The groove 162, outer rubbing element 158, inner rubbing element 160 and the spindle 44 are configured such that the friction between the inner rubbing element 160 and the spindle 44 is greater than the friction between the outer rubbing element 158 and the groove 162. This configuration results in the seal 106 being rotatably fixed to the spindle 44 while free to rotate inside the groove 162 of the bearing adapter 104.

[40] Looking to FIG. 8, the external seal 130 of the second bearing assembly 48 includes a rubber portion 164 and a metal portion 166. The rubber portion 164 includes an outer rubbing element 168. The outer rubbing element 168 is received in a groove 170 in the flange portion 134 of the second bearing adapter 128. The groove 170 is configured such that the rubber portion 164 of the seal 130 must be slightly deformed when it is installed into the groove 170. Once the rubber portion 164 is installed, it will substantially return to its original shape and thereby be retained in the groove 170. An inner diameter of the metal portion 166 of the seal 130 is slightly larger than the inner diameter of the bearing reducer 132. If the crank assembly 10 does not include the bearing reducer 132 then the inner diameter of the metal portion 166 is slightly larger than the inner diameter of the bearing 126. With this configuration, the spindle 44 is easily inserted through the bearing 126 without contacting the seal 130.

[41] Looking to FIGS. 9-11, the fastener 55 for tightening the non-drive crank arm 52 onto the spindle 44 includes a bolt 172, a washer 174 and a cup 176. The washer 174 has an inner side surface 178 and an outer side surface 180. The inner side surface 178 of the washer 174 abuts against the surface 100 in the cylindrical bore 94 of the non-drive crank arm 52. The bolt 172 includes a flange portion 182, a threaded portion 184 and a tool-engaging portion 186. The threaded portion 184 mates with the threads 70 on the spindle 44. The flange portion 182 includes an inner side surface 188 and an outer side surface 190. The inner side surface 188 is perpendicular to a bolt axis 192 and abuts against the outer side surface 180 of the washer 174. The outer side surface 180 of the bolt 172 is at an angle # relative to the bolt axis 192; in this embodiment the angle # equals 60 degrees but may be anywhere between 40 and 75 degrees. The angle # of the outer side surface 190 allows the cup 176 to be smaller in axial direction than if the outer side surface 190 were perpendicular to the bolt axis 192 because the contact area between the outer side surface 190 of the bolt 172 and an inner side surface 192 of the cup 176 is greater, thereby reducing the contact stress. The tool-engaging portion 186 is formed on an inner surface of a bore 194 extending through the bolt 172 such that an assembly tool (not shown) can non-rotatably engage the bolt 172 for tightening. In this embodiment, the tool-engaging portion 186 is shaped to interface with a standard Allen wrench.

[42] The cup 176 includes a threaded portion 196 and a flange portion 198. The threaded portion 196 mates with corresponding threads 70 on the non-drive crank arm

52. The flange portion 198 includes an inner side surface 200 and a tool-engaging portion 202. The inner side surface 200 is oriented at an angle θ relative to the axis of the threaded portion 196 of the cup 176. The angle θ of the inner side surface 200 corresponds to the outer side surface 190 of the bolt 172 such that the two side surfaces 190, 200 abut against each other. The tool-engaging portion 202 is formed on a bore 204 extending through the flange portion 198 of the cup 176. In this embodiment, the tool-engaging portion 202 includes a plurality of splines 206 for non-rotatably engaging with a plurality of splines on an assembly tool (not shown). Alternatively, the tool-engaging portion 202 may include a standard tool interface pattern such as that found on an Allen or Torx wrench. Regardless of the shape, the diameter of the tool-engaging portion 202 of the cup 176 is larger than the diameter of the tool-engaging portion 186 of the bolt 172 so that the tool may pass through the tool-engaging portion 202 of the cup 176 without interference to tighten the bolt 172.

[43] The cup 176 provides an axial stop for the bolt 172. When the bolt 172 is loosened, the bolt 172 contacts the cup 176 and thus pushes the non-drive crank arm 52 off of the spindle 44, resulting in the crank assembly 10 being easily disassembled. Further to ensure that the crank assembly 10 may be easily disassembled, the friction between the outer side surface 190 of the bolt 172 and the inner side surface 200 of the cup 176 should be smaller than the friction between the threaded portion 196 of the cup 176 and the threads 70 on the non-drive crank arm 52. This may be accomplished through the use of a friction modifying coating on either the cup 176 or bolt 172 such as PTFE impregnation. Alternatively, a friction-reducing washer may be disposed between the bolt 172 and the cup 176. In other embodiments of the present invention, the cup 176 may be eliminated. A disassembly tool may be used to remove the non-drive crank arm 52 from the spindle 44. The cup 176 is not required for proper operation of the crank assembly 10.

[44] The crank assembly 10 shown in FIGS. 1-11 is assembled as follows. The spacer tube 53 is installed into the first bearing assembly 46 and then the first and second bearing assemblies 46, 48 are screwed into the frame shell 26. Thus the spacer tube 53 is disposed between the bearing assemblies 46, 48 and serves to seal the bearing assemblies 46, 48 from any contamination that enters the frame shell 26. Integrated spindle 44 on the drive crank arm 50 is then inserted through the first bearing assembly 46 and the second bearing assembly 48 until the shoulder portion 66 contacts flange portion 150 of the bearing reducer 132. Non-drive crank arm 52 is then installed onto the non-drive adapting portion 68 of the spindle 44. The bolt 172 is threaded into the spindle threaded portion 70 and tightened, drawing the crank arm 52 onto the spindle 44 until the inner side surface 96 contacts the external seal 130. As the bolt 172 is tightened, washer 174, non-drive crank arm 52, seal 130, bearing 126 and bearing reducer 132 are clamped tightly between bolt flange 182 and the spindle shoulder 66.

[45] FIG. 12 illustrates a spindle 300 and drive crank arm 302 for the crank assembly in

accordance with another embodiment of the present invention. In this embodiment, the spindle 300 is integrally bonded with the drive crank arm 302 which is made from a fiber-resin composite material. The drive crank arm 302 includes a pedal adapting portion 304, fiber-resin composite shell 306, and interior foam portion 308. Support projections 310 are provided on either the drive crank arm 302 or the spindle 300 for receiving at least one chainring 40 for driving the chain 38 to propel the bicycle 12.

[46] The spindle 300 includes a drive adapting portion 312, bearing race portions 314, 316, a shoulder portion 318, a non-drive adapting portion 320 and a threaded portion 322. The drive adapting portion 320 includes a smooth continuous surface having a plurality of protrusions (not shown). The fiber-resin composite shell 306 of the drive crank arm 302 is formed over the interior foam portion 308 and the drive adapting portion 312 of the spindle 300 and cured such that the spindle 300 is integrally bonded with the drive crank arm 400 in a non-rotatable manner.

[47] FIG. 13 illustrates a spindle 400 and drive crank arm 402 of the crank assembly in accordance with another embodiment of the present invention. In this embodiment, the spindle 400 is monolithically formed with the drive crank arm 402 using common three-dimensional forming technology such as forging or casting. The drive crank arm 402 includes a pedal adapting portion 404 and a drive crank arm portion 406. Support projections 408 are provided on either the drive crank arm 402 or spindle 400 for attaching at least one chainring 40 for driving the chain 38 to propel the bicycle 12. The spindle 400 includes bearing race portions 408, 410, a shoulder portion 412, a non-drive adapting portion 414 and a threaded portion 416.

[48] The crank assembly 10 is rotatably mounted to the frame shell 26 by both bearing assemblies 46, 48 but fixed in an axial direction only by the bearing assembly 48 that is located farthest from the chainring 40. The first bearing assembly 46 that is located closest to the chainring 40 is not constrained in an axial direction on the spindle 44 such that it can only carry radial loads. Thus, bearing loads are balanced between the bearing assemblies 46, 48 such that the lives of the bearings 102, 126 are maximized. Additionally, tolerances associated with differing lengths of the frame shell 26 do not affect the axial bearing loads because the first bearing assembly 46 is free to move in an axial direction on the spindle 44 to accommodate for these different lengths. Further, there is no need for the assembler to manually adjust the axial distance between bearing assemblies 46, 48 to satisfy a predetermined axial bearing load allowance. In this way, the bearing assemblies 46, 48 are not subjected to axial force as a result of the installation and their service life is not affected by assembly practices. Finally, assembly and disassembly of the entire system is quick and simple with a minimum of required tools.

[49] While this invention has been described by reference to a preferred embodiment, it should be understood that numerous changes could be made within the spirit and scope of the inventive concepts described. Accordingly, it is intended that the invention not

be limited to the disclosed embodiment, but that it have the full scope permitted by the language of the following claims.

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

☐ **BLACK BORDERS**

☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**

☒ **FADED TEXT OR DRAWING**

☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**

☐ **SKEWED/SLANTED IMAGES**

☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**

☐ **GRAY SCALE DOCUMENTS**

☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**

☐ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**

☐ **OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.